भारतीय मानक
Indian Standard

IS 17293 : 2020

रेटेड वोल्टेज 1 500 डी. सी. की फोटोवोल्टिक प्रणालियों के लिए इलेक्ट्रिक केबल

Electric Cables for Photovoltaic Systems for Rated Voltage 1 500 V d.c.

ICS 29.060.20, 27.160

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Electric Cables Sectional Committee, ETD 09

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Electric Cables Sectional Committee, had been approved by the Electrotechnical Division Council.

A solar cable is the interconnection cable used in photovoltaic power generation. Solar cables interconnect solar panels and other electrical components of a photovoltaic system. In PV system, one of the important parts is the solar cable connected on d.c. side of the system. These cables are suitable for outdoor long term installations which are under directly exposed to solar radiations and humidity. Hence, stringent requirements for insulation and sheath are set for these cables. These cables are designed to operate at a normal continuous conductor temperature of 90° C.

This standard covers the requirements for single core cables for use in Photovoltaic Systems (PV) for installation at the direct current side (d.c). In order to ensure that the cables are weather and PV resistant, the test requirements like, thermal endurance test, weathering/UV resistance on sheath, ozone resistance on complete cable, sheath resistance against acid alkaline solution, long term resistance of insulation and surface resistance of sheath are incorporated in the standard. The standard contains the test requirements, method of tests, and guide of cables giving recommendations for use of cable, bending radii, current carrying capacity and reduction factors.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis shall be rounded off in accordance with IS 2 : 1960 ‘Rules for rounding off numerical values (*revised*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard

Indian Standard

ELECTRIC CABLES FOR PHOTOVOLTAIC SYSTEMS FOR RATED VOLTAGE 1 500 V d.c.

1 SCOPE

This standard covers single core cables for use in photovoltaic (PV) systems for installation at the direct current side (d.c.). These are suitable for outdoor long-term installations directly exposed to solar radiations. Since these cables are directly exposed to direct Sun radiations, air humidity etc, stringent requirements are set for these cables. These requirements ensure that the cables are weather and UV resistant. These cables are designed to operate at a normal continuous conductor temperature of 90°C. The permissible period of use at a maximum conductor temperature of 120°C is limited to 20 000 h.

2 REFERENCES

The standards given below contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards:

IS No.	*Title*
1885 (Part 32) : 1993	Electrotechnical vocabulary
4905 : 2015	Random sampling and randomization procedures
8130 : 2013	Conductors for insulated electric cables and flexible cords
8504 (Part 1) : 2012	Thermal endurance properties of electrical insulating materials — Ageing procedures and evaluation of test results
8504 (Part 2) : 2013	Thermal endurance properties of electrical insulating materials : Determination of Thermal Endurance properties of electrical insulating material — Choice of test criteria
10810	Method of test for cables:
(Part 0) : 1984	Method of test of cables: General
(Part 1) : 1984	Annealing test for wires used in conductors
(Part 4) : 1984	Persulphate test of conductor
(Part 5) : 1984	Conductor resistance test
(Part 6) : 1984	Thickness of thermoplastic and elastomeric insulation and sheath
(Part 7) : 1984	Tensile strength and elongation at break of thermoplastic and elastomeric insulation and sheath
(Part 11) : 1984	Thermal ageing in air
(Part 12) : 1984	Shrinkage test
(Part 20) : 1984	Cold bend test
(Part 21) : 1984	Cold impact test
(Part 43) : 1984	Insulation resistance
(Part 44) : 1984	Spark test
(Part 45) : 1984	High voltage test
(Part 53) : 1984	Flammability test
(Part 59) : 1988	Determination of the amount of halogen acid gas evolved during combustion of polymeric materials taken from cables
(Part 63) : 1993	Smoke density of electric cables under fire conditions
(Part 30) : 1984	Hot Set test

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 1885 (Part 32) and IS 10810 (Part 0) and the following shall apply.

3.1 Type Tests — Tests required to be made before supplying a type of cable covered by this standard on a general commercial basis in order to demonstrate satisfactory performance characteristics to meet the intended application. These tests are of such a nature that, after they have been made, they need not be repeated unless changes are made in the cable materials or design or manufacturing process, which might change the performance characteristics.

3.2 Acceptance Tests — Tests carried out on samples taken out from a lot for the purpose of acceptance of lot.

3.3 Routine Tests — Tests conducted by manufacturer on all finished lengths to demonstrate the integrity of the cable.

3.4 Nominal Value — The value by which a quantity is designated and which is often used in tables. Usually, in this standard, nominal values give rise to values to be checked by measurements taking into account specified tolerances.

SECTION 1 GENERAL REQUIREMENTS

4 CONDUCTOR

4.1 Material

The conductor shall consist of annealed tinned copper wires complying with class 5 as per IS 8130 for cable that is directly connected to PV module. The conductor for cables intended for fixed installations and not directly connected to the PV modules shall be annealed tinned copper of Class 2 as per IS 8130.

A separator tape made of suitable material may be applied over conductor at the discretion of the manufacturer.

5 INSULATION

5.1 Material

The insulation shall be cross-linked compound and shall satisfy the requirements as specified in Table 11 of Annex B.

5.2 Application to the Conductor

The insulation shall be so applied by extrusion, such that it fits closely on the conductor. It shall be possible to remove it without damage to the insulation itself, to the conductor or to the tin coating, if any. Compliances shall be checked by visual inspection. It is permitted to apply the insulation in a single layer or in a number of coherent layers. When more than one layer is used, all testing shall be carried out on the complete insulation as though it were a single layer.

5.3 Thickness

The average thickness of insulation shall be not less than the specified value for each type and size of cables given in the Table 1 and 2 as applicable.

The smallest of the measured values of thickness of insulation (t_1) shall not fall below the nominal value (t_i) specified in the table by more than (0.1 mm + $0.1t_i$).

6 SHEATH

6.1 Material

The sheath material shall be cross-linked and comply with the requirement as specified in Table 11 of Annex B.

6.2 Application

The sheath shall be applied homogenously by extrusion. It is permitted to apply the sheath in a single layer, or number of coherent layers. When more than one layer is used, all testing shall be carried out on the complete sheathing as though it were a single layer.

The sheath shall not adhere to the core. A separator, consisting of a film or tape, or talcum powder may be placed under the sheath.

6.3 Thickness

The average thickness of sheath shall be not less than the specified value for each size and type of cable given in Table 1 and Table 2 as applicable. The smallest of the measured values of thickness of sheath shall not fall below the nominal value (t_s) specified in the table by more than (0.1 mm+ $0.15t_s$).

6.4 Colour

The colour of the sheath shall preferably be black. Any other colour as agreed between the manufacturer and customer is also permissible. A symbol " +" OR "-" may be used to identify the polarities, on the same base colour of sheath.

7 OVER ALL DIMENSIONS

The mean over all diameter of the cables shall be as given in the Table 1 and Table 2.

8 CABLE IDENTIFICATION

The printing, indentation or embossing shall be done on the sheath. The manufacturer shall be identified throughout the length of the cable by manufacturer's name or trade-mark being printed, indented or embossed on the cable. Cables shall be marked with the nominal cross sectional area, for example, "1.5 sqmm". Cables shall also be marked with code designation 'PV'. Additionally, cable shall also be marked with words 'HALOGEN FREE LOW SMOKE'. The distance between any two consecutive printing, indentation or embossing shall not be more than 550 mm.

8.1 Continuity of Marking

Each specified marking shall be regarded as continuous if the distance between the end of the mark and the beginning of the next identical mark does not exceed 550 mm.

NOTE — A specified marking is any mandatory marking covered by this standard.

Table 1 Dimensions and Insulation Resistance (for Class 5 Conductors)

(*Clause* 6.3, 7, 11.2.3, 11.3.3 *and* Table 3)

Sl No. (1)	**Nominal Cross-sectional Area of Conductor** mm² (2)	**Thickness of Insulation** mm (3)	**Thickness of Sheath** mm (4)	**Mean Overall Diameter *** mm (5)	**Minimum Insulation Resistance at 20°C** MΩ.km (6)	**Minimum Insulation Resistance at 90°C** MΩ.km (7)
i)	1.5	0.7	0.8	5.4	1050	1.05
ii)	2.5	0.7	0.8	5.9	862	0.862
iii)	4.0	0.7	0.8	6.6	709	0.709
iv)	6.0	0.7	0.8	7.2	610	0.610
v)	10.0	0.7	0.8	8.3	489	0.489
vi)	16.0	0.7	0.9	9.8	393	0.393
vii)	25.0	0.9	1.0	12.2	395	0.395
viii)	35.0	0.9	1.1	14.0	335	0.335
ix)	50.0	1.0	1.2	16.3	314	0.314
x)	70.0	1.1	1.2	18.7	291	0.291
xi)	95.0	1.1	1.3	20.8	258	0.258
xii)	120.0	1.2	1.3	23.0	249	0.249
xiii)	150.0	1.4	1.4	25.7	260	0.260
xiv)	185.0	1.6	1.6	28.7	268	0.268
xv)	240.0	1.7	1.7	32.3	249	0.249
xvi)	300.0	1.8	1.8	35.6	237	0.237
xvii)	400.0	2.0	2.0	40.6	230	0.230

* Indicative value for information only

Table 2 Dimensions and Insulation Resistance (for Class 2 Conductors)

(*Clause* 6.3 *and* 7)

Sl No. (1)	**Nominal Cross-sectional Area of Conductor** mm² (2)	**Thickness of Insulation** mm (3)	**Thickness of Sheath** mm (4)	**Mean Overall Diameter *** mm (5)	**Minimum Insulation Resistance at 20°C** MΩ.km (6)	**Minimum Insulation Resistance at 90°C** MΩ.km (7)
i)	16.0	0.7	0.9	9.5	374	0.374
ii)	25.0	0.9	1.0	11.8	384	0.384
iii)	35.0	0.9	1.1	13.2	327	0.327
iv)	50.0	1.0	1.2	15.1	317	0.317
v)	70.0	1.1	1.2	17.3	291	0.291
vi)	95.0	1.1	1.3	19.6	251	0.251
vii)	120.0	1.2	1.3	21.6	244	0.244
viii)	150.0	1.4	1.4	24.0	254	0.254
ix)	185.0	1.6	1.6	27.0	261	0.261
x)	240.0	1.7	1.7	30.4	243	0.243
xi)	300.0	1.8	1.8	33.5	231	0.231
xii)	400.0	2.0	2.0	37.7	227	0.227

* Indicative value for information only

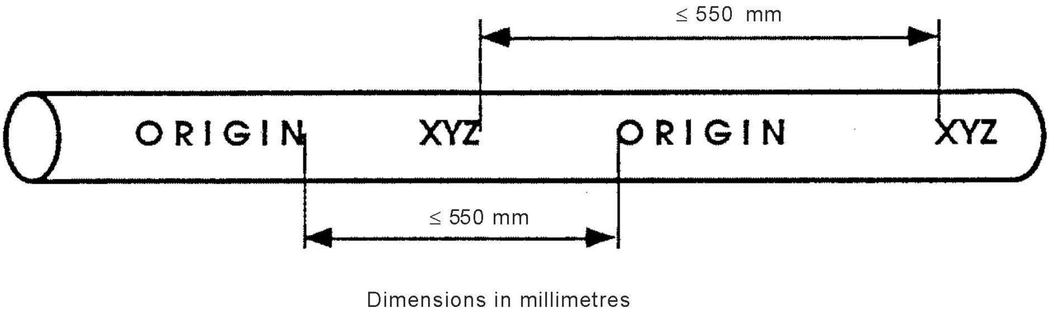


FIG. 1 EXAMPLE OF MARKING AS USED ON THE OUTER SHEATH OF THE CABLE

Figure 1 shows an example of marking as used on outer sheath of the cable.

Other marking, such as, that required under recognized volunteer third party approval schemes, may also follow the requirements of this sub clause.

8.2 Durability

In case of printed marking, it shall be durable. The durability of printed marking shall be checked by trying to remove the marking by rubbing lightly ten times with a piece of cotton wool or cloth soaked in water.

8.3 Legibility

All markings shall be clear and legible.

9 CORE IDENTIFICATION

The preferred colour of the insulated core is red or black. Any other colour scheme agreed to between the purchaser and manufacturer is also permissible.

9.1 General Requirements

Identification of the cores of a cable shall be achieved by the use of coloured insulation or other suitable method. The colouring with skin type is allowed provided it meets the desired testing as given in the standard.

9.1.1 *Colour Combination*

It is permissible to provide stripes in case of colour combination. In such case, the distribution of the colours shall comply with the following condition:

For every 15 mm length of cores one of these colours shall cover approximately, but not exceeding, 70 percent of the surface of the core, the other colour covering the remainder.

10 SAMPLING OF CABLES

Number of Drums/Coils/ Number of Reels in the lot	Number of Drums/Coils/ Reels to be Taken as sample	Permissible Defectives
(*n*)	(*n*)	(*a*)
Up to 50	3	0
51-100	5	0
101 to 300	8	0
301 and above	13	2

11 REQUIREMENTS FOR COMPLETED CABLES

11.1 General

The tests to be carried out on cables specified in this standard shall be as scheduled in Table 3 which refers to the relevant clauses of the standard specifying the requirements and test methods for type test, routine tests and acceptance tests as defined in Table **3**.

11.2 Electrical Tests

11.2.1 *Voltage Tests on Completed Cable*

Cables shall be immersed in water at ambient temperature 1 h before the testing and the test voltage of 6.5 kV a.c or 15 kV d.c shall be applied between conductor and water for duration of 5 min. No break down shall occur.

11.2.2 *Spark Test*

Spark test shall be carried out as per IS 10810 (Part 44) on single core sheathed cables. The voltage shall be as specified below:

Tabulated Radial Thickness (Nominal) of Cable Under Test (*mm*)		Test Voltage kV			
Above	Up to and including	a.c[a]	d.c.	h.f.[a] (High frequency)	Pulse[a]
0	0.25	3	5	4	5
0.25	0.50	5	7	6	7
0.50	0.75	6	9	7	9
0.75	1.00	7	11	8	11
1.00	1.25	9	13	10[ab]	13
1.25	1.50	10	15	11[ab]	15
1.50	1.75	12	17	13[ab]	17
1.75	2.00	13	20	14[ab]	20
2.00	2.25	14	22	15[ab]	—
2.25	2.50	16	24	17[ab]	—
2.50	2.75	17	26	18[ab]	—
2.75	3.00	19	28	20[ab]	—
3.00	3.25	21	32	—	—
3.25	3.50	23	35	—	—
3.50	—	25	38	—	—

[a] The a.c. and h.f. test voltages are r.m.s. values, the pulse test voltage is the peak value.

[ab] h.f. voltage testing for cable thicknesses greater than 1.00 mm shall be limited to frequency between 500 Hz to 4kHz

11.2.3 *Measurement of Insulation Resistance*

Cable shall be tested at 20°C and at 90°C. The insulation resistance shall not be less than the values stated in Table 1 for the relevant conductor size.

11.2.4 *Long-term Resistance of Insulation to d.c.*

The core shall be carefully removed from a sample approximately 5 m long from the finished cable. Core shall be so immersed in a water bath at 85 ± 5°C that their ends protrude at least 250 mm above the water level. A voltage of 1.8 kV d.c. shall be applied between conductor and water. The core shall withstand this d.c. voltage test for total 240 h without breakdown.

After the test, exterior of the insulation shall show no sign of damage. Discoloration of the insulation should be ignored.

11.2.5 *Surface Resistance of Sheath*

11.2.5.1 *Test samples*

Carry out the test on three samples of completed cable.

11.2.5.2 *Procedure*

a) Clean the sheath of each of the samples with industrial methylated spirit, and apply to each sample two electrodes, consisting of wire helices of copper wire of between 0.2 mm and 0.6 mm diameter, at a distance of (100 ± 2) mm from each other. After the wire has been applied, clean the surface of the sheath again thoroughly between the electrodes.
b) Condition the samples with electrodes attached in a conditioning chamber at a temperature of (20 ± 2)°C and a relative humidity of (65 ± 5) percent for 24 h.
c) Immediately after removal from the conditioning chamber, apply a d.c. voltage of between 100 V and 500 V between the electrodes, and measure the resistance after 1 min.
d) Multiply the measured resistance of each sample, in ohm, by $a/100$, where 'a' is the circumference of sheath of the sample, in mm. Record the median of the three values so obtained as the surface resistance of the sheath. This value shall be not less than 10^9 ohm.

11.3 Non Electrical Tests

11.3.1 *Sheath Colour*

The colour throughout the sheath shall be checked by visual examination and shall be in accordance with **6.4**.

11.3.2 *Sheath Marking*

The marking on the sheath shall comply with the requirements given in **8**. These shall be checked by visual examination and measurement.

11.3.3 *Overall Diameters and Ovality*

Informative values on maximum overall diameters of the cables are given in Table 1.

Ovality of the cables shall be limited. The difference between maximum and minimum measured values of the overall diameter of sheathed circular cable shall not exceed 15 percent of the maximum measured value at the same cross section.

12 PACKING AND MARKING

12.1 The cable shall be either wound on drums or reels or supplied in coils packed.

12.2 The cable shall carry the following information either stenciled on the reel or drum or contained in a label attached to it:

a) Reference to this Indian Standard, for example, IS ------;
b) Manufacturer’s name, brand name or trade- mark;
c) Voltage grade;
d) Code designation that is “PV”.
e) Number of cores;
f) Nominal cross-sectional area of conductor;
g) Word “ATC”;
h) Colour of sheath, for example, black;
j) Length of cable on the reel, drum or coil;
k) Number of lengths on the reel, drum or coil (if more than one);
m) Direction of rotation of drum (by means of arrow) in case packed in wooden drums;
n) Country of manufacture; and
p) Year of manufacture.

12.3 BIS Certification Marking

12.3.1 The product may also be marked with the standard mark.

12.3.2 The use of Standard Mark is governed by the Bureau of Indian Standards Act, 2016 and the rules and Regulations Made thereunder. The details of the conditions under which the licence for use of the Standard Mark may be granted to manufacturer and producers may be obtained from the Bureau of Indian Standards.

Table 3 Tests for Cables

(*Clause* 11.1)

Sl No.	Test	Unit	Method of test Ref to Part of IS 10810 / Clause of This Standard	Requirements Ref. to IS No./ Clause or Table of This Standard	Type of Test
(1)	(2)	(3)	(4)	(5)	(6)
1	**Electrical tests**				
1.1	Conductor resistance test		Part 5	IS 8130	R,A,T
1.2	Voltage test on completed cable with a.c or d.c		Part 45	**11.2.1**	A,T
1.2.1	Test conditions:				
	– minimum length of the sample	m		20	
	– minimum period of immersion in water	h		1	
	– temperature of the water	°C		27± 2	
1.2.2	Voltage applied (a.c) or	kV		6.5	
	Voltage applied (d.c) or	kV		15	
1.2.3	Duration of application of voltage, minimum	min		5	
1.2.4	Result to be obtained			No breakdown	

Table 3 (*Continued*)

Sl No.	Test	Unit	Method of test Ref to Part of IS 10810 / Clause of This Standard	Requirements Ref. to IS No./ Clause or Table of This Standard	Type of Test
(1)	(2)	(3)	(4)	(5)	(6)
1.3	Check of absence of faults on the insulation (or on completed cable)				
1.3.1	Result to be obtained		Part 44, **11.2.2**	No fault shall be detected	R
1.4	Measurement of the insulation resistance		Part 43		A,T
1.4.1	At 27°C				
1.4.1.1	Test conditions :				
	– length of sample	m		5	
	– minimum period of immersion in water	h		2	
	– temperature of the water	°C		27±2	
1.4.1.2	Result to be obtained	MΩ.km		Min. as stated in Table 1	
1.4.2	At 90°C				
1.4.2.1	Test conditions :				
	– length of sample	m		5	
	– minimum period of immersion in hot water	h		2	
	– temperature of the water	°C		90±2	
1.4.2.2	Result to be obtained	MΩ.km		Min. as stated in Table 1.	
1.5	Long term resistance of insulation to d c		**11.2.4**	**11.2.4**	T
1.5.1	Test conditions :				
	– length of sample	m		5	
	– duration of test	h		240	
	– water temperature	°C		85 ± 5	
	– d.c. voltage applied	kV		1.8	
1.5.2	Result to be obtained			No breakdown and no signs of damage	
1.6	Surface resistance of sheath		**11.2.5.2**	**11.2.5.2**	T
1.6.1	Test conditions :				
	– voltage applied, d.c.	V		100 to 500	
	– duration of test	min		1	
1.6.2	Result to be obtained	ohm		$\geq 10^9$	
2	**Constructional and dimensional tests**				
2.1	**Conductor**		Part 4	Not to be exceeded as stated in **6.4.3** and Table 3 of IS 8130	T
2.1.1	Maximum diameter of wire in conductor	mm			
2.1.2	Checking continuity of tin (Persulphate test)			IS 8130, **7.1.1**	

Table 3 (*Continued*)

Sl No.	**Test**	**Unit**	**Method of test Ref to Part of IS 10810 / Clause of This Standard**	**Requirements Ref. to IS No./ Clause or Table of This Standard**	**Type of Test**
(1)	(2)	(3)	(4)	(5)	(6)
2.2	Insulation				
2.2.1	Insulation thickness	mm	Part 6	Not less than stated in **5.3**, Table 1and Table 2.	T,A
2.3	Sheath				
2.3.1	Sheath thickness	mm	Part 6	Not less than stated in **6.3** , Table 1 and Table 2.	
2.4	Ovality		**11.3.3**		T,A
2.4.1	Ovality value	%		**11.3.3**	
2.5	Sheath colour		Visual	**6.4**	T,A
2.5.1	Visual examination			**6.4**	
2.6	Sheath marking				T,A
2.6.1	Visual examination and measurement		**9**	**9**	
3	**Insulation material**			Table 11	T
4	**Sheath material**			Table 11	T
5	**Compatibility test**		Part 11 (Three test pieces of complete cable approx. 200 mm long cable to be suspended in the oven.)		T
5.1	**Test conditions :**				
	– duration of test	h		168	
	– temperature	°C		135 ± 2	
5.2	Result to be obtained			Sl No. 1.8.2 and 1.8.3 of Table 11	
6	**Cold impact test**		Part 21		T
6.1	Test conditions :			Annex C	
6.2	Result to be obtained			No cracks	
7	**Cold bend test (**bending at low temperature**)**		Part 20 [a]		T
	Cable diameter ≤ 12.5 mm				
7.1	Test conditions :				
	– conditioning duration	h		16	
	– temperature	°C		– 40 ± 2	
7.2	Result to be obtained			No cracks	

Table 3 (*Continued*)

Sl No.	**Test**	**Unit**	**Method of test Ref to Part of IS 10810 / Clause of This Standard**	**Requirements Ref. to IS No./ Clause or Table of This Standard**	**Type of Test**
(1)	(2)	(3)	(4)	(5)	(6)
8	**Elongation at low temperature** (Cold elongation)		Annex F		T
	Cable diameter > 12.5 mm				
8.1	Test conditions :				
	– conditioning duration	h		16	
	– temperature	°C		– 40 ± 2	
	Values to be obtained, *Min.*	%		30	
9	**Ozone resistance on complete cable**		Annex G		T
9.1	Test conditions :				
	– temperature	°C		25 ± 2	
	– duration	h		24	
	– ozone concentration (by volume)	%		(250 to 300) × 10^{-4}	
9.2	Result to be obtained [b]			No cracks	
10	**Weathering / UV resistance on sheath**		Annex E	Annex. E	T
10.1	Test conditions :			Annex. E	
10.2	Result to be obtained			Annex. E	
11	**Dynamic penetration test**		Annex D		T
11.1	Test conditions			Annex D	
11.2	Result to be obtained			Annex D	
12	**Damp heat test**		Annex H		T
12.1	Test conditions :				
	– temperature	°C		90	
	– duration	h		1 000	
	– relative humidity min	%		85	
	– reconditioning period	h		16 to 24	
12.2	Result to be obtained on the sheath				
	– for tensile strength, variation maximum	%		– 30 [c]	
	– for elongation at break, variation maximum	%		– 30 [c]	
13	**Shrinkage test on sheath**		Part 12		T
13.1	Test conditions :				
	– temperature	°C		120	
	– Number of cycles	Number		5	

Table 3 (*Concluded*)

Sl No.	Test	Unit	Method of test Ref to Part of IS 10810 / Clause of This Standard	Requirements Ref. to IS No./ Clause or Table of This Standard	Type of Test
(1)	(2)	(3)	(4)	(5)	(6)
	– duration of each cycle	h		1	
	– length of sample	mm		300	
13.2	Results to be obtained				
	– maximum shrinkage	%		2	
14	**Test for vertical flame propagation on complete cable**		Part 53		T
14.1	Results to be obtained			Cable shall pass the test if the distance between the lower edge of the top support and the onset of charring is greater than 50 mm. In addition, charring shall not extend downwards to a point greater than 540 mm from the lower edge of the top support.	
15	**Smoke emission of complete cable**		Part 63		T
15.1	Results to be obtained – light transmittance , min	 %		 60	
16	**Assessment of halogens for all non-metallic materials**		Annex J		T
16.1	Results to be obtained			Annex J	

[a] *See* Table 4 for number of turns and diameter of mandrel.

[b] Any cracks near the fixing point on the mandrel and /or near the clamps when using test strips shall be disregarded.

[c] No positive value of variation defined.

Table 4 Number of Turns and Diameter of Mandrel

(Table 3)

Sl No.	Overall Diameter, *d*, of the Test Piece mm	Number of Turns
(1)	(2)	**(3)**
i)	d ≤2 .5	10
ii)	2.5 < d ≤ 4.5	6
iii)	4.5 < d ≤ 6.5	4
iv)	6.5 < d ≤ 8.5	3
v)	8.5 < d	2

ANNEX A

(*Informative*)

GUIDE TO USE

A-1 USE OF CABLES FOR PV SYSTEMS

Following information and those from Table 5 and Table 6 shall be taken in to account for the products specified in this standard.

The d.c voltage rating of the cables is 1.5 kV, both between conductors as well as between conductors and earth. The maximum permitted operating d.c voltage of the systems, in which the cables specified in this standard are applied, shall not exceed 1.8 kV.

The a.c voltage rating of the specified cables is 1/1 kV (U_O/U). The rated voltage in an a.c system is expressed by the combination of two values U_O/U, expressed, in kV, where:

a) U_O is the r.m.s. value between any insulated conductor and earth; and

b) U is the r.m.s. value between any two phases.

Table 5 Recommended Use of Cables for PV Systems

(*Clause* A-1)

Construction (1)	**Recommended Use** (2)	**Comments** (3)
Cables for PV- systems	Intended for use in PV installations. They are intended for permanent use outdoor and indoor. Cables with class 5 conductors are suitable for free movable, free hanging and fixed installation while class 2 conductors are limited to fixed installations where no flexing (for example engagement or disengagement of the conductor) is expected. It is also permitted to install the cables in conduit or trunking systems. They are not intended for direct burial. Halogen free low smoke cables are intended to reduce the risks for people and goods in the event of fire. Suitable for the application in/at equipment with protective insulation.	For recommended bending radii, *see* Table 6. For recommended current capacities of cables, *see* Table 7. Max. storage Temperature: +45°C Min. temperature for Installation and handling: 25°C

Table 6 Minimum Recommended Bending Radii at Cable Temperature of (20 ± 10)°C

(Table 5)

Cable Type	**Minimum Bending Radius**			
	Cable Diameter ≤8 mm	Cable Diameter >8≤12 mm	Cable Diameter >12≤20 mm	Cable Diameter >20 mm
(1)	(2)	(3)	(4)	(5)
Cables for fixed installation :				
a. Normal use	4D	5D	6D	6D
b. Careful bending at termination	2D	3D	4D	4D
Flexible cables :				
a. Fixed installation	3D	3D	4D	4D
b. Free movement	4D	4D	5D	6D
D = Overall diameter of cable.				

Table 7 Current Carrying Capacity of PV Cables

(Table 5)

Sl No.	Nominal Cross-sectional Area	Current Carrying Capacity According to Method of Installation		
		Single cable free in air	Single cable on a surface	Two loaded cables touching, on a surface
	mm²	A	A	A
(1)	(2)	(3)	(4)	(5)
i)	1.5	28	27	22
ii)	2.5	38	36	30
iii)	4.0	52	49	41
iv)	6.0	66	63	53
v)	10.0	89	87	73
vi)	16.0	120	118	97
vii)	25.0	167	158	126
viii)	35.0	207	196	156
ix)	50.0	261	248	190
x)	70.0	329	313	245
xi)	95.0	394	374	298
xii)	120.0	462	440	348
xiii)	150.0	537	510	401
xiv)	185.0	611	581	460
xv)	240.0	735	698	545
xvi)	300.0	831	788	631
xvii)	400.0	999	947	751

Ambient temperature : 40°C (*see* Table 8 for other ambient temperatures)

Max conductor temperature : 90°C

Table 8 Current Rating Conversion Factors for Different Ambient Temperatures

(Table 7)

Sl No.	Ambient Temperature (°C)	Conversion Factor
(1)	(2)	(3)
i)	0	1.34
ii)	10	1.26
iii)	20	1.19
iv)	30	1.10
v)	40	1.00
vi)	50	0.90
vii)	60	0.78
viii)	70	0.64

A-2 GROUPS

For installation in groups the reduction factors for current rating according to Table 9 shall apply.

A-3 SHORT-CIRCUIT-TEMPERATURE

The permitted short-circuit-temperature is 250°C for a maximum period of 5 s.

Table 9 Reduction Factors for One Circuit or for a Group of More than One Circuit to be used with Current-Carrying Capacities of Table 7

(*Clause* A-2)

Sl No.	Arrangement (Cable Touching)	Number of Circuits											
		1	2	3	4	5	6	7	8	9	12	16	20
i)	Bunched in air, on a surface, embedded or enclosed	1.00	0.80	0.70	0.65	0.60	0.57	0.54	0.52	0.50	0.45	0.41	0.38
ii)	Single layer on wall, floor or unperforated cable tray systems	1.00	0.85	0.79	0.75	0.73	0.72	0.72	0.71	0.70	No further reduction factor for more than nine circuits or multicore cables		
iii)	Single layer on a perforated horizontal or vertical cable tray systems	1.00	0.88	0.82	0.77	0.75	0.73	0.73	0.72	0.72			
iv)	Single layer on cable ladder systems or cleats etc.	1.00	0.87	0.82	0.80	0.80	0.79	0.79	0.78	0.78			

NOTES:

1 These factors are applicable to uniform groups of cables, equally loaded.

2 Where horizontal clearances between adjacent cables exceeds twice their overall diameter, no reduction factor need to be applied.

3 The same factors are applied to :

a) Groups of two or three single core cables;

b) Multicore cables.

4 If a group consists of n single core cables, it may either be considered as n/2 circuits of two loaded conductors or n/3 circuits of three loaded conductors.

5 For some installations and other methods, not provided for in the above table, it may be appropriate to use factors calculated for specific cases.

ANNEX B

(*Clause* 5.1 *and* 6.1)

REQUIREMENTS FOR INSULATION AND SHEATHING MATERIALS

Table 11 Requirements for Insulation and Sheathing Materials

(*Clause* 5.1 *and* 6.1)

Sl. No (1)	**Tests** (2)	**Unit** (3)	**Test Method Standard** (4)	**Type of Compound** (5)	 (6)
1	**Mechanical Characteristics** [a]			Insulation	Sheath
1.1	Properties before ageing [b]		IS 10810 (Part 7)		
1.1.1	Values to be obtained for tensile strength				
	– median [c], *Min.*	N/mm^2		8.0	8.0
1.1.2	Values to be obtained for the elongation at break – median[c], *Min.*	%		125	125
1.2	Properties after ageing in oven		IS 10810 (Part 11)		
1.2.1	Test conditions [b] :				
	– temperature	°C		150 ± 2	150 ± 2
	– duration of treatment	h		168	168
1.2.2	Values to be obtained for tensile strength – variation, *Max.*	%		-30 [d]	-30 [d]
1.2.3	Values to be obtained for the elongation at break – variation, *Max.*	%		-30 [d]	-30 [d]
1.3	Hot set test [b]		IS 10810 (Part 30)		
1.3.1	Test conditions:				
	– temperature	°C		200±3	
	– time under load	min		15	
	– mechanical stress.	N/cm^2		20	
1.3.2	Values to be obtained				
	– elongation under load, *Max.*	%		100	
	– permanent elongation after cooling, *Max.*	%		25	
1.4	Thermal endurance Test conditions [b] :		IS 8504 (Part 1) and (Part 2)		
1.4.1	Elongation at break shall be performed				
	– temperature index corresponding to 20 000 h		IS 8504 (Part 2)	≥ 120	≥ 120
	– elongation at break, *Min.*	%		50	50
1.5	Bending at low temperature Insulated conductor/cable overall diameter ≤12.5 mm		IS 10810 (Part 20) [e]		
1.5.1	Test conditions:				
	– temperature	°C		-40 ± 2	-40 ± 2
	– Duration	h		16	16
1.5.2	Results to be obtained			No cracks	No cracks
1.6	Elongation at low temperature Insulated conductor/cable overall diameter ≤12.5 mm		Annex F		

Table 11 (*Concluded*)

Sl. No	Tests	Unit	Test Method Standard	Type of Compound	
(1)	(2)	(3)	(4)	(5)	(6)
1.6.1	Test conditions [b]:				
	– temperature	°C		-40 ± 2	-40 ± 2
	– Duration	h		4	4
1.6.2	Value to be obtained				
	– elongation at break, *Min.*	%		30	30
1.7	Sheath resistance against acid and alkaline solution		Annex I		
1.7.1	Test conditions [f]:				
	– acid solution : N-Oxalic acid				
	– alkaline solution : N-Sodium hydroxide				
	– temperature	°C			23 ± 2
	– Duration of treatment	h			168
1.7.2	Values to be obtained for tensile strength				
	– variation, *Max.*	%			±30
1.7.3	Values to be obtained for the elongation at break, *Min.*	%			100
1.8	Compatibility test		11 (Three test pieces of complete cable aprox. 200 mm long cable to be suspended in the oven.)		
	Test conditions				
	– temperature	°C		135±2	135 ± 2
	– Duration of treatment	h		168	168
	Values to be obtained for tensile strength				
	– variation, *Max.*	%		±30	±30 [d]
	Values to be obtained for the elongation at break				
	– variation, *Max.*	%		±30	±30 [d]

[a] If the insulation and sheath stick together and it is not possible to prepare separated specimen for insulation and sheath, the tubular test piece shall be tested and results applied to both insulation and/or sheath as required.

[b] This test shall be performed on test samples of insulation and sheath compound obtained from completed cables.

[c] median value of five test pieces.

[d] No positive value for variation defined.

[e] *see* Table 4 for number of turns and diameter of mandrel.

[f] 'N' means 1 Normal concentration.

ANNEX C

(Table 3)

C-1 METHOD FOR COLD IMPACT TEST

The cold impact test shall be performed at -40°C according to IS 10810 (Part 21). The mass of the hammer, the mass of steel intermediate piece and height shall comply with Table 12. The cable shall be inspected with normal or corrected vision without magnification. No cracks shall be determined

Table 12 Parameters for Cold Impact Test

(*Clause* C-1)

Sl No.	Cable Diameter (D)	Mass of Hammer	Mass of Steel Intermediate Piece	Height
	mm	g	g	mm
(1)	(2)	(3)	(4)	(5)
i)	D ≤15	1 000	200	100
ii)	15 < D ≤ 25	1 500	200	150
iii)	D > 25	2 000	200	200

ANNEX D

(Table 3)

DYNAMIC PENETRATION TEST

D-1 A test apparatus suitable for pull testing (or an equivalent apparatus) shall be operated in pressure mode and shall be equipped with a measuring device which is able to record the force of penetration of a spring-steel-needle through the insulation or sheath of a completed cable (*see* Fig. 2, the test is made with side of the needle not with the point of the needle). A circuit with low voltage, which is interrupted at the moment when the needle penetrates the sheath and the insulation and makes contact with the conductor, shall be added.

D-2 The test shall be performed at room temperature. The force applying to the needle shall be increased continuously with 1 N/s until contact with the conductor has been made. Four tests on each sample shall be performed and the force at the moment of contact shall be recorded. After each test, the sample shall be moved forward and shall be turned clockwise for 90°.

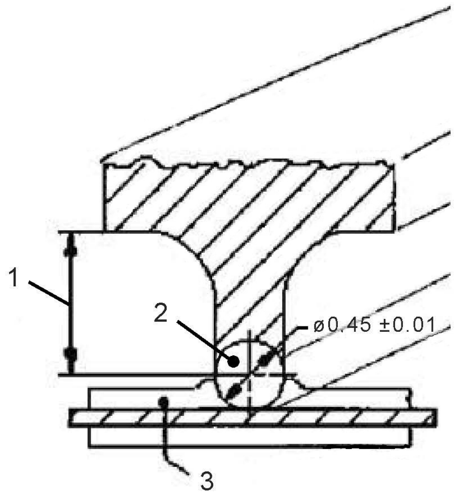
D-3 The mean value of the four test results shall not be less than the minimum value F determined with the following formula

$$F = 150\sqrt{d_L}$$

Where,

F = value of the test force, in N; and

d_L = diameter of conductor, in mm.



Dimensions in millimeters

Key

1 Shoulder with sufficient depth for testing the insulation

2 Needle of spring steel

3 Sample

FIG. 2 ARRANGEMENT FOR DYNAMIC PENETRATION TEST

ANNEX E

(Table 3)

WEATHERING /UV RESISTANCE TEST

E-1 This test is to determine the UV stability of the sheathing material of the cable in the condition as manufactured. This is done by means of measuring tensile strength and elongation at break in the condition as manufactured and after exposure to ultraviolet light and water.

E-2 The testing apparatus is equipped with following :

a) a ray source consisting of xenon arc lamp with borosilicate filters so that the typical irradiance should be 60 W/m^2 ± 15 percent with a spectrum between 300 nm and 400 nm;

b) a means to provide automatic control of temperature, humidity and cycles;

c) a generator of deionized water with a conductivity not greater than 5 µS/cm; the rate of flow should be sufficient to guarantee that all the test specimens can be washed.

d) a means to control the irradiance.

E-3 A sample of the finished cable shall be selected to prepare 10 test pieces in accordance with IS 10810 (Part 7).

E-4 Five test pieces shall be exposed to the treatment for 720 h in 360 cycles of 120 min defined as follows :

a) 102 min of dry radiation exposure at a temperature of (60 ± 3)°C and relative humidity of (50 ± 10) percent, followed by

b) 18 min of rain exposure, without radiation, at a temperature of (50 ± 3)°C without control of relative humidity.

After the exposure, the test specimens shall be removed from the equipment and conditioned at ambient temperature for at least 16 h.

The five exposed test pieces and the five not exposed test pieces shall be tested separately and in close succession for tensile strength and elongation at break. The respective median values shall be calculated from the five tensile strength and elongation at break values obtained for the conditioned test pieces and shall be divided by the median values of the five tensile strength and elongation at break values obtained for the unconditioned test pieces.

The tensile-strength and elongation at break after 720 h (360 cycles) of exposure shall be at least 70 percent of the values measured on not exposed test pieces.

ANNEX F

(Table 3, Annex B *and* Table 11)

METHOD FOR ELONGATION AT LOW TEMPERATURE TEST

F-1 GENERAL

This test is performed on insulated conductor/cable having overall diameter greater than 12.5 mm.

F-1.1 Sampling

Each core/cable to be tested shall be represented by two samples of suitable length.

F-1.2 Preparation of Test Pieces

The insulation/sheath shall be cut open in the direction of the axis.

The insulation/sheath need not to be ground or cut if the inner and outer surfaces are smooth and its mean specified thickness does not exceed 2 mm. The samples having the thickness exceeding this limit, or samples having imprints or ridges on the inner side, shall be ground or cut to obtain two parallel and smooth surfaces, and thickness which does not exceed 2.0 mm. The minimum thickness after grinding or cutting shall be 0.80 mm, but if the original thickness of the insulation/sheath does not allow it, then 0.6 mm shall be permitted as the minimum thickness. Grinding and cutting shall be carefully carried out to avoid undue heating and mechanical stresses in the insulation/sheath.

All strips shall be conditioned at least 3 h.

After the preparation, two dumb-bells from each sample, in accordance with Fig. 1 or if necessary Fig. 2 of IS 10810 (Part 7), shall be punched in the direction of the axis of each sample. If, possible, two dumb-bells shall be punched side by side.

F-2 APPARATUS

When cooling in air, the conditioning time for cooling the apparatus and test piece together shall be at least 4 h. If the apparatus has been pre-cooled, this period may be reduced to 2 h, and if the apparatus and test piece have been pre-cooled, the conditioning time after the test piece has been fixed in the apparatus, shall not be less than 1 h.

F-3 PROCEDURE AND TEST CONDITIONS

In both pre-cooled grips, the dumb-bell shall be clamped over the same length.

The free length between the grips shall be about 30 mm for both types of dumb-bells if the direct measurement of the distance between marker lines is to be made during the test.

If the displacement of the grips is to be measured, the free length between shall be (30 ± 0.5) mm for the dumb-bell in accordance with Fig.1 of IS 10810 (Part 7), and (22 ± 0.5) mm for the dumb-bell in accordance with Fig. 2 of IS 10810 (Part 7).

The speed of separation of the grips of the tensile machine shall be (25 ± 5) mm/min.

The elongation shall be determined by measuring the distance between the marker lines, if possible, or between the grips at the moment of the rupture.

F-4 EVALUTION OF THE RESULTS

For calculating the elongation, the increase of the distance between the marker lines shall be related to the initial distance of 20 mm [or 10 mm if the dumb-bell in accordance with Fig. 2 of IS 10810 (Part 7)] is used and expressed as a percentage of this distance. If the alternative method of measuring distance between the grips is used, the increase of this distance shall be related to the original distance being 30 mm for the dumb-bell in accordance with Fig. 1, and 22 mm for dumb-bell according to Fig. 2 of IS 10810 (Part 7). When this method is used, the test piece shall be examined before being removed from the apparatus. If the test piece has partly slipped out of the grips, the results shall be ignored at least 3 valid results are required for calculating the elongation, otherwise the test shall be repeated.

Unless otherwise specified, none of the valid results shall be less than 20 percent. In case of dispute, the method employing marker lines shall be used.

ANNEX G

(Table 3)

METHOD FOR OZONE RESISTANCE TEST ON COMPLETE CABLE

G-1 APPARATUS

The following apparatus shall be used:

a) a device for generating a controlled amount of ozone;
b) a means for circulating ozonized air under controlled conditions of humidity and temperature through a chamber containing the test pieces to be tested;
c) a means for determination of ozone concentration;
d) a suitable device for clamping and elongation of test pieces;
e) cylindrical mandrels consisting of wood or metal;
f) a desiccator filled with silica gel or equivalent material; and
g) an accurate laboratory balance reading to 0.1 mg.

G-2 SAMPLING AND PREPARATION OF TEST PIECES

Sufficient length of the cable shall be cut from a position not less than 1.5 m from the end of the length of the cable to provide two test pieces.

Any sample that shows signs of mechanical damage shall not be used for the tests.

G-3 CONDITIONING AND DEFORMATION PROCEDURE OF TEST PIECES

One test piece shall be bent in the direction and plane of its existing curvature, without twisting, for one complete turn, around a mandrel and bound with twine or tape where the ends cross, and a second test piece of the same core shall be bent similarly in the plane of its existing curvature but in the opposite direction.

The bending shall be carried out at the temperature 20°C to 28°C using a brass, aluminum or suitably treated wooden mandrel with the diameter according to Table 13.

If the test piece is too rigid to permit the ends to be crossed it shall be bent and tied so that at least 180° bend round a mandrel of the specified diameter is obtained.

Table 13 Mandrel Diameters

(*Clause* G-3)

Outside Diameter of Insulated Core (*d*) (mm)	**Mandrel Diameter (as Multiple of the Outside Diameter of Insulated Core**
$d \leq 12.5$	4±0.1
$12.5 < d \leq 20$	5±0.1
$20 < d \leq 30$	6±0.1
$30 < d \leq 45$	8±0.1
$45 < d$	10±0.1

Surface of each test piece shall be wiped with a clean cloth to remove dirt or moisture. The bent test pieces on the mandrels shall be kept in air at ambient temperature without any further treatment for 30 min to 45 min before being tested.

G-4 EXPOSURE TO OZONE

The conditioned test pieces prepared shall be placed in the middle of the test chamber fitted with a test cock; the test pieces shall be at least 20 mm from each other. The test pieces shall be maintained at a temperature of (25 ± 2)°C and exposed to a circulating current of dry air with the required ozone concentration.

The ozone concentration may be measured directly with an ozone meter which has been calibrated by comparison with results obtained by the chemical method.

The air with the required ozone concentration shall have a flow rate of between 280 l/h and 560 l/h and the air pressure shall be maintained slightly above atmospheric pressure.

G-5 EVALUATION OF RESULTS

After the specified test duration, the test pieces shall be removed from the test chamber and examined with normal or corrected vision without magnification.

The cable in the 180° of the bent portion furthest from the tie shall be free from cracks. Any cracks near the clamps shall be disregarded.

ANNEX H

(*Table* 3)

METHOD FOR DAMP HEAT TEST

H-1 GENERAL TEST PROCEDURE

H-1.1 Test Chamber and Measuring System

The chamber and measuring system shall be such that:

a) sensing devices can be located in the working space to monitor the temperature and humidity;
b) condensed water is drained from the chamber and not re-used unless purified;
c) no condensed water from the wall and roof of the test chamber can fall on the specimen (s);
d) water utilized to maintain humidity levels has electrical conductivity of not more than 20 µS/cm;
e) the specimen under test shall not be subjected to radian heat from the chamber conditioning devices;
f) injected moisture, when applicable, is injected remotely from the specimen and without being directly on it;
g) the volume of the test chamber is at least five times the total volume of the specimen under test; and
h) a mounting device, when used, has minimum influence on the heat and humidity exchanges between specimen and surrounding conditions, unless otherwise specified in the relevant specification.

H-2 TESTING PROCEDURE

The specimen shall be introduced in the chamber which is maintained at 90 ± 2°C and 85 percent of RH. Expose the specimens to the test conditions and duration as specified. After the conditioning at the prescribed severity (combination of temperature, relative humidity RH and total test duration) as given in Table 3. Before the final measurement, the recovery procedure shall be followed.

H-2.1 Recovery Procedure

All specimens should be dried at room temperature for 16 to 24 h.

H-2.2 Final Measurement

The specimens shall be visually inspected and mechanically checked for tensile strength and elongation.

ANNEX I

(Annex B *and* Table 11)

SHEATH RESISTANCE AGAINST ACID AND ALKALINE SOLUTION

I-1 SCOPE

This method typically applies to cross-linked compounds used for sheathing materials.

I-2 TEST METHOD

K-2.1 General

This test shall be carried out at room temperature.

I-2.2 Pre-conditioning

All the test shall be carried out not less than 16 h after the extrusion or cross-linking of sheathing compounds.

I-2.3 Sample and Test Piece Preparation

Five test pieces shall be prepared in accordance with the procedure described is IS 10810 (Part 7).

I-2.4 Solutions to be Used

1 N oxalic acid or 1 N sodium hydroxide.

I-2.5 Procedure

The test pieces shall be immersed in the standard solutions described above for the specified period. At the end of the specific duration, the test pieces shall be removed from the solution, blotted lightly to remove excess solution and suspended in air at the ambient temperature for at least 16 h but not more than 24 h unless otherwise specified in the relevant cable standard. At the end of this period any further excess solution shall be removed by lightly blotting the test pieces.

I-2.6 Determination of Mechanical Properties

This test shall be carried out as per IS 10810 (Part 7).

I-2.7 Expression of Results

The calculation of tensile strength shall be based on the cross-sectional area of the test piece measured before immersion.

The difference between the median value obtained on the 5 test pieces immersed in solution and the median value of the values obtained for the untreated test pieces expressed as a percentage of the latter, shall not exceed the percentage specified in the standard for the cable.

ANNEX J

(Table 3)

ASSESSMENT OF HALOGENS

J-1 REQUIREMENTS

J-1.1 The insulation and sheath shall meet the type test requirements as given below:

Sl No.	Test Method	Measure	Requirements
1	*See* **J-2**	pH and conductivity	pH ≥ 4.3 and conductivity ≤ 10 µS/mm
2	IS 10810 (Part 59)	Chlorine and Bromine content expressed as content of HCL	≤ 0.5 percent
3a	*See* **J-3**	Presence of fluorine	If negative, Stop further test. If positive, test as per 3b
3b	*See* **J-4**	Fluorine content	≤ 0.1 percent

J-1.2 The material shall be tested as per given sequence as given below:

Sl No	Test Method	Measure	Requirements	Outcome
Step 0	*See* **J-3**	Halogen : Fluorine, Chlorine and Bromine	Negative value	If negative stop test – material accepted. If positive go to step 1
Step 1	*See* **J-2**	pH	pH < 4.3	Reject the material
			pH ≥ 4.3	Evaluate Conductivity
		Conductivity	≤ 2.5µ S/mm	Accept no further testing required
			> 10 µS/mm	Reject material
			> 2.5 <10	Chlorine bromine determination as per *See* **J-3**
Step 2	IS 10810 (Part 59)	Chlorine and Bromine content expressed as HCL	> 0.5 Percent	Reject material
			≤ 0.5 Percent	*See* **J-4**
	See **J-4**	Fluorine content	> 0.1 Percent	Reject material
			≤ 0.1 Percent	Accept material

J-2 DETERMINATION OF DEGREE OF ACIDITY OF COMBUSTION GASES FOR MATERIAL BY MEASURING PH AND CONDUCTIVITY

J-2.1 Test Method Principle

The material under test shall be heated in a stream of dry air. The evolved gases shall be trapped by bubbling through wash bottles filled with distilled or demineralized water.

The acidity of the resulting solution shall be assessed by determination of its pH value. The conductivity of the solution shall also be determined.

J-2.2 Test Apparatus

J-2.2.1 *General*

The apparatus is shown in Fig. 3 to Fig. 7.

The assembly of the components which constitute the test apparatus shall be leak tight. The connecting distances between the quartz glass tube and the first bottle and between subsequent bottles shall be as short as possible. Glass or silicone rubber tubing shall be used for these connections.

NOTES:

1 At the exit side of the quartz glass tube, as close to the end as possible, it is permitted to place a plug of silica wool to aid collection of condensates.

2 A third empty bottle, of the same size as the gas washing bottles, placed before the gas washing bottles may be used to improve safety, that is, to prevent suck back of water into the quartz glass tube.

J-2.2.2 *Tube Furnace*

The length of the heating zone of the furnace shall be within the range 480 mm to 620 mm and its inside diameter shall be within the range 38 mm to 62 mm.

It shall be equipped with an adjustable electrical heating system.

J-2.2.3 *Quartz Glass Tube*

For the test, a quartz glass tube shall be introduced into the tube furnace. The tube shall be approximately concentric to the furnace. It shall be resistant to the action of corrosive gases.

The inside diameter of the tube shall be within the range 30 mm to 46 mm. The tube shall protrude on the entrance side of the furnace by a length of between 60 mm to 200 mm, and on the exit side by between 60 mm to 100 mm. The initial clearance shall allow for thermal expansion. For the purposes of measurement of the protrusion distances, the tube shall be regarded as that part of essentially constant diameter.

NOTE — The outer diameter of the tube should be chosen with due regard to the inside diameter of the tube furnace.

Prior to each test the tube shall be cleaned throughout its length by being calcined at approximately 950°C.

J-2.2.4 *Combustion Boats*

The combustion boat shall be made of porcelain, fused quartz or soapstone and shall have the following dimensions:

a) *External Length* : within the range 45 mm to 100 mm;

b) *External Width* : within the range 12 mm to 30 mm; and

c) *Internal Depth* : within the range 5 mm to 10 mm.

NOTE — The dimensions of the boat should be chosen with due regard to the inside diameter of the quartz tube.

The preferred method for insertion of the combustion boat into the quartz glass tube is shown in Fig. 3.

Prior to each test, the combustion boat shall be washed and calcined in a muffle furnace at approximately 950 °C for 4 h after which it shall be introduced into a desiccator and cooled to ambient temperature. The combustion boat shall then be weighed to an accuracy of 0.1 mg until two identical consecutive weights are obtained. This weight *m*1 shall be recorded.

J-2.2.5 *Bubbling Devices for Gases*

At the exit of the quartz glass tube, the evolved gases shall be trapped by bubbling through two wash bottles (*see* Fig. 4), each containing approximately 450 ml of distilled or demineralized water of a purity at least Grade 3 in accordance with IS 1070.

The *p*H value of the water shall be 6.5 ± 1, and the conductivity less than 0.5 mS/mm.

A magnetic stirrer shall be introduced in the first gas washing bottle to get a good swirling motion and an effective absorbtion of the combustion gases. The tubes into the wash bottles shall have a maximum internal diameter at their tip of 5 mm in order to aid absorption. The height of the liquid above the end of the tube shall be (110 + 10) mm in each bottle.

NOTE — Use of a standard laboratory glass bottle of internal diameter approximately 75 mm will enable this requirement to be met.

J-2.2.6 *Air Supply System*

The gas used for combustion shall be air.

The flow rate of air introduced into the quartz tube shall be adjusted according to the actual internal cross-sectional area of the tube, such that the speed of air flowing across the sample is approximately 20 ml/ mm2/h.

The speed of air shall be regulated by reference to the flow rate of air. The flow rate of air shall be (0.0157 × *D*2) l/h with a tolerance of ±10 percent.

NOTE — The derivation of the flow rate of air from the speed of air is:

$$\rho = V \times \frac{\pi D^2}{4}$$

Where,

ρ = flow rate of air (ml/h); and
V = speed of air (ml/mm2/h).
D = internal diameter of the tube (mm);

The air supply shall be adjusted and controlled by a needle valve, and the flow rate monitored by a flowmeter of the appropriate range.

The air supplied shall be selected from one of the following methods:

a) *Method 1*

This method uses synthetic air or compressed air from a bottle. The air shall be introduced on the inlet side of the quartz glass tube (*see* Fig. 5).

b) *Method 2*

This method uses a laboratory compressed air supply. Air shall be introduced on the inlet side of the quartz glass tube and shall be filtered and dried (*see* Fig. 6).

c) *Method 3*

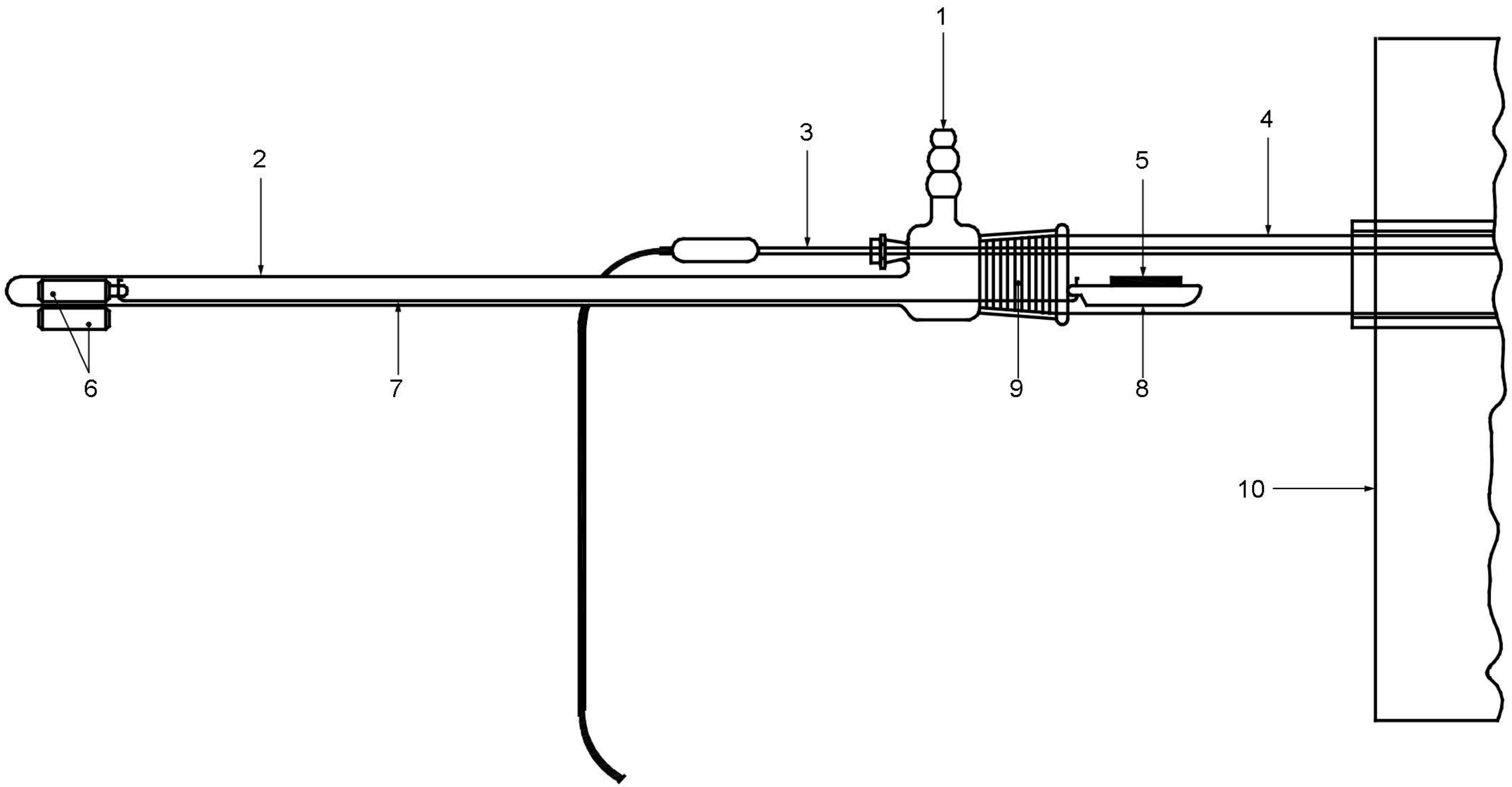
This method uses the ambient air of the laboratory. The air shall be filtered and dried. In this case, the mixture of air and combustion gas shall be sucked by a pump (*see* Fig. 7).

J-2.2.7 *Analytical Balance*

The balance shall have a precision of ± 0.1 mg.

J-2.2.8 *Laboratory Glassware*

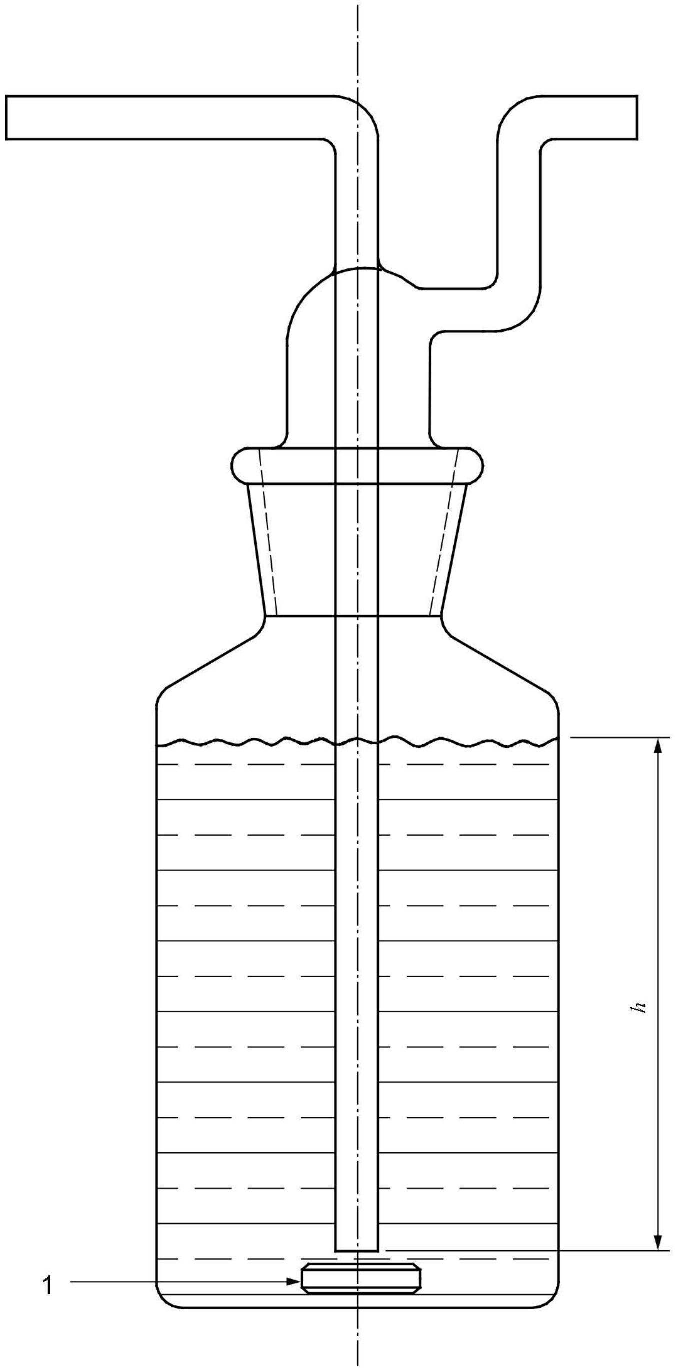
For *p*H and conductivity determination, the following laboratory glassware shall be available: one mark volumetric flask in accordance of IS 915 with 1 000 ml capacity.



Key

1	Synthetic air or compressed air, filtered and dried	6	Bar magnets
2	Glass tube	7	Platinum wire
3	Thermocouple	8	Combustion boat
4	Quartz glass tube	9	Standard ground joint, size in correlation to the diameter of the quartz glass tube
5	Test specimen	10	Furnace

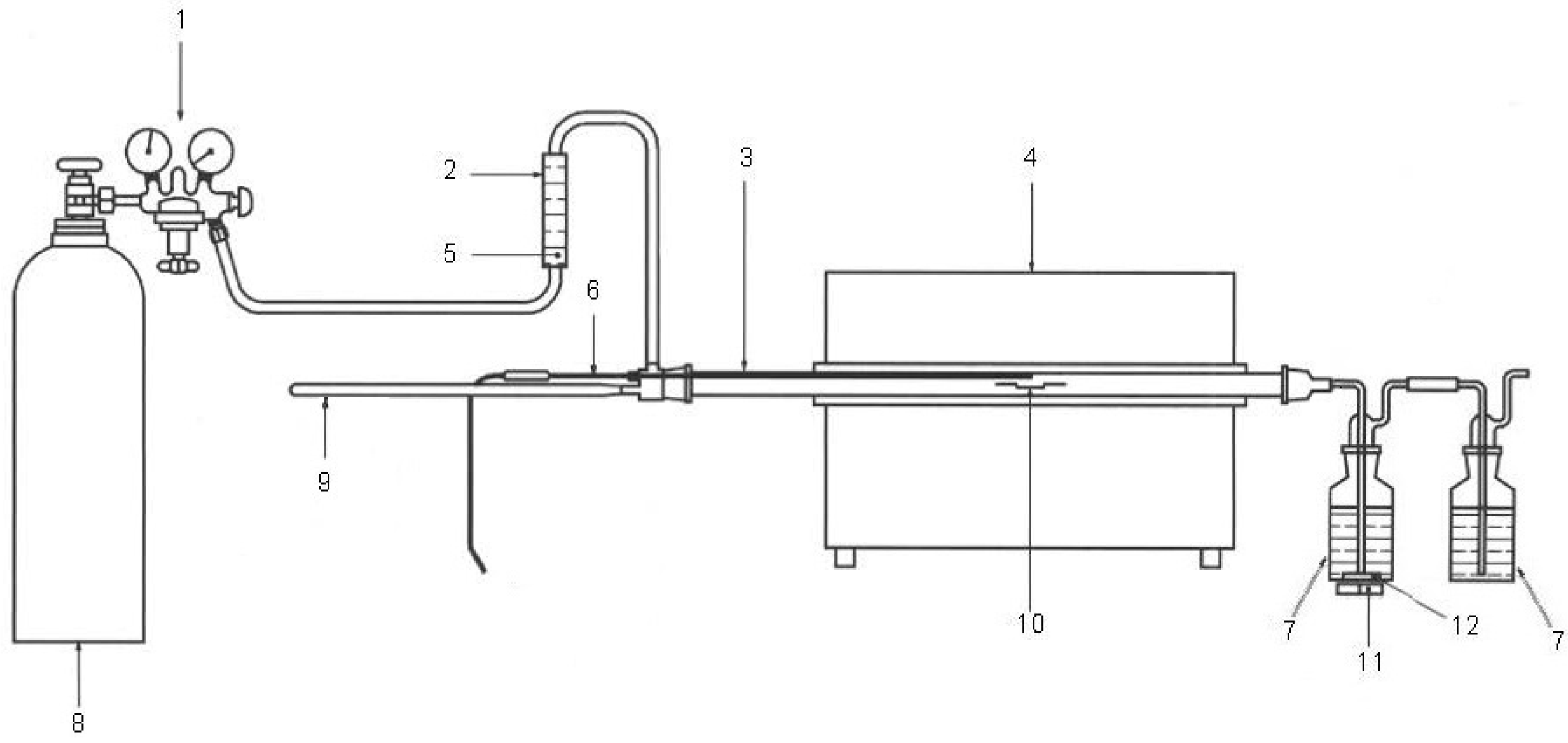
FIG. 3 DEVICE FOR INSERTING COMBUSTION BOAT AND TEST SPECIMEN



Key

1	Magnetic stirring bar	*h*	100 mm to 120 mm

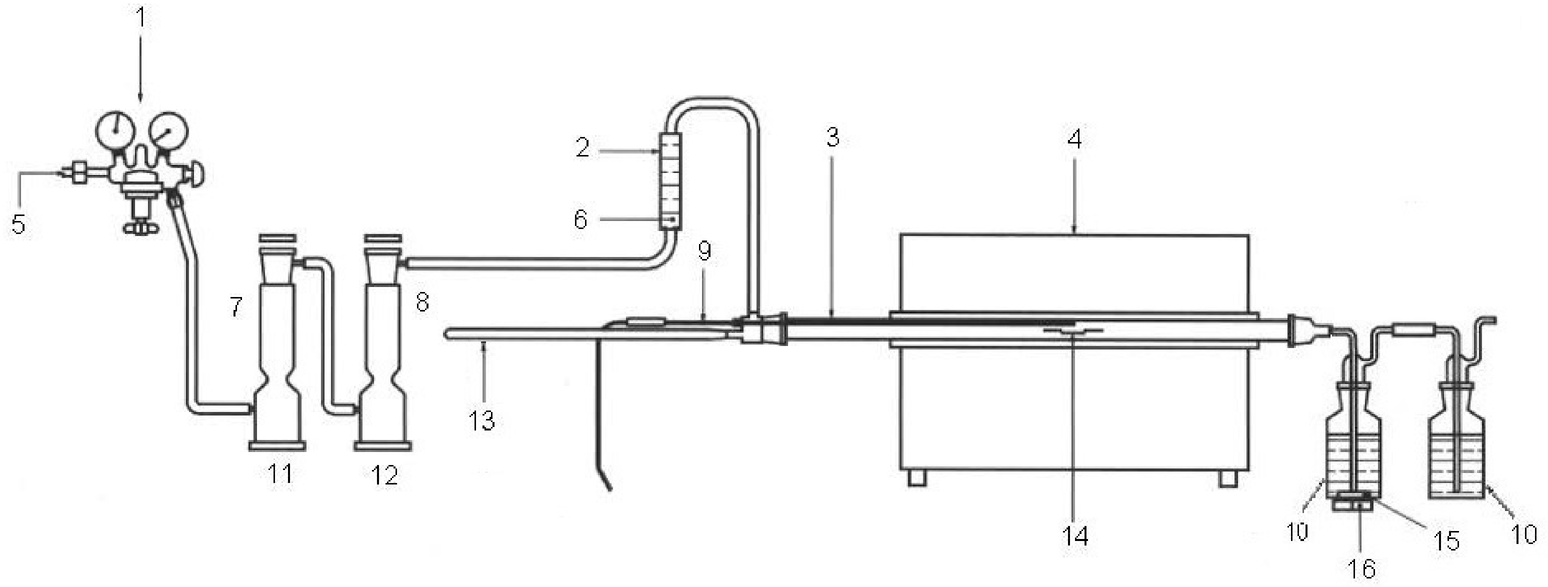
FIG. 4 EXAMPLE OF A GAS WASHING BOTTLE



Key

1	Pressure reducing valve	7	Gas washing bottles
2	Flow meter	8	Synthetic air
3	Quartz glass tube	9	Device for inserting combustion boat containing test specimen
4	Furnace	10	Combustion boat containing test specimen
5	Needle valve	11	Magnetic stirrer
6	Thermocouple	12	Magnetic stirring bar

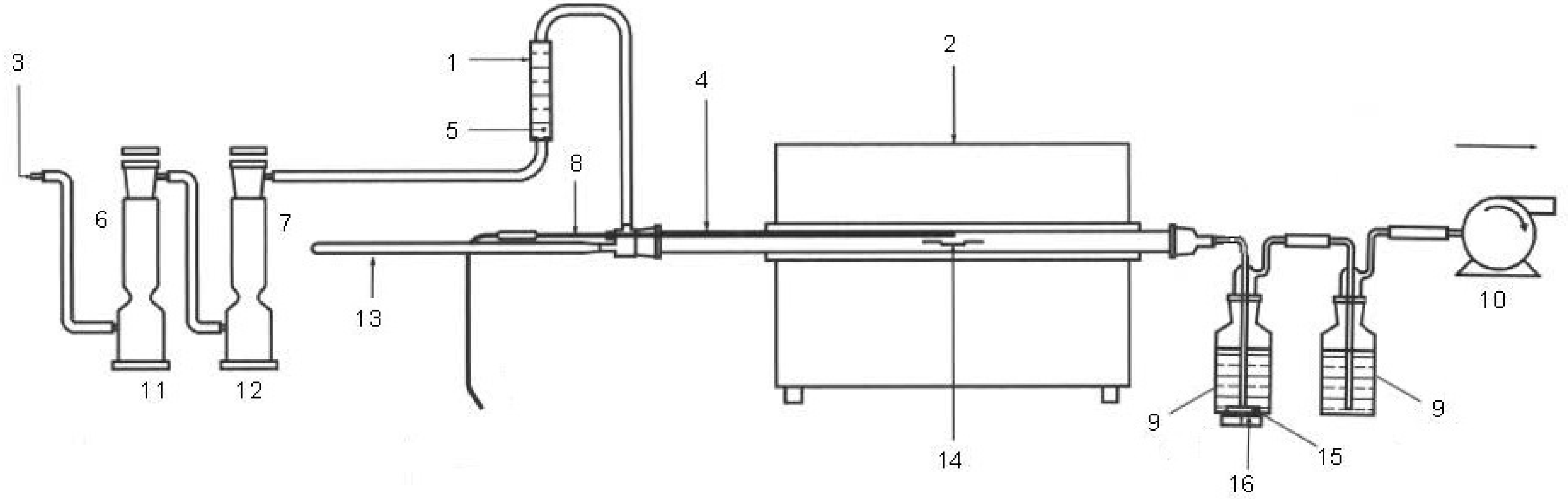
FIG. 5 TEST APPARATUS: METHOD 1 – USE OF SYNTHETIC OR COMPRESSED AIR FROM A BOTTLE



Key

1	Pressure reducing valve	7	Activated charcoal	13	Device for inserting combustion boat containing test specimen
2	Flow meter	8	Silica gel	14	Combustion boat containing test specimen
3	Quartz glass tube	9	Thermocouple	15	Magnetic stirring bar
4	Furnace	10	Gas washing bottles	16	Magnetic stirrer
5	Compressed air	11	Air filtering		
6	Needle valve	12	Air drying		

FIG. 6 TEST APPARATUS: METHOD 2 — USE OF LABORATORY COMPRESSED AIR SUPPLY



Key

1	Flowmeter	7	Silica gel	13	Device for inserting combustion boat containing test specimen
2	Furnace	8	Thermocouple	14	Combustion boat containing test specimen
3	Ambient air	9	Gas washing bottles	15	Magnetic stirring bar
4	Quartz gass tube	10	Suction pump	16	Magnetic stirrer
5	Needle valve	11	Air filtering		
6	Activated charcoal	12	Air drying		

FIG. 7 TEST APPARATUS: METHOD 3 – USE OF AMBIENT AIR SUCKED BY MEANS OF A SUCTION PUMP

J-2.2.9 *pH Meter*

The *p*H meter shall have a precision of +0.02 and shall be equipped with a *p*H electrode.

J-2.2.10 *Conductivity Measuring Device*

The conductivity measuring device shall have a range of 10^{-1} µS/mm to 10^{+2} µS/mm and shall be equipped with an electrode.

J-2.3Test Specimen J-2.3.1 *General*

Three test specimens for the general method, or two for the simplified method, each consisting of (1 000 ± 5) mg of the material to be tested, shall be prepared. Each test specimen shall be taken from a sample representative of the material. Each test specimen shall be cut into a number of smaller pieces.

NOTE — Pieces with a maximum dimension of 3 mm have been found to be suitable.

J-2.3.2 *Conditioning of Specimen*

The prepared test specimens shall be stored for at least 16 h at a temperature of (23 ± 2)°C and a relative humidity of (50 ± 5) percent.

J-2.4 Test Procedure J-2.4.1 *General*

The test procedure and determination of *p*H value and conductivity value shall be carried out on each test specimen.

J-2.4.2 *Test Apparatus and Arrangement*

The test procedure defined in this clause shall be carried out using the apparatus detailed in **J-5**.

J-2.4.3 *Heating Procedure*

The air flow shall be adjusted by means of a needle valve to the value specified in

J-2.2.6 and shall be kept constant during the test.

The temperature shall be measured by a thermocouple suitably protected against corrosion and placed inside the quartz glass tube. The heating system shall be adjusted such that the temperature at the designated position for the boat shall be not less than 935°C and not more than 965°C. The temperature at a position 300 mm from the designated position in the direction of the air flow shall be not less than 900°C.

The boat containing the test specimen shall be quickly inserted into the heating zone of the tube to the designated position determined by the thermocouple measurement and the timer shall be started. The combustion boat shall be placed in such a way that the distance between the boat and the exit end of the effective heating zone is at least 300 mm. The effective heating zone is that zone where a temperature of not less than 900°C has been determined by the thermocouple measurement.

The combustion procedure, under the air flow condition, shall be continued for (30 ± 1) min in the furnace.

WARNING — The operator should take precautions, e.g. the wearing of eye protection and suitable protective clothing, because certain materials ignite quickly, and can cause “b low back” of hot gases. Care should also be taken to avoid over-pressurization of the system, and to allow for venting of exhaust gases. Guidance on the avoidance of “blow back” is given in NOTE 2 of **J- 2.2.1**.

J-2.4.4 *Washing Procedure*

Following the heating procedure, all the bottles used shall be disconnected, and the contents washed into a 1 000 ml volumetric flask. Using water with the properties given in **J-2.2.5**, the bottles, the connecting links and, after cooling, the end of the quartz glass tube including the silica wool (if used) shall also be washed into the flask, and the contents made up to 1 000 ml.

J-2.5 Determination of the *p*H Value and Conductivity

The *p*H shall be measured using a *p*H meter calibrated as proposed by the instrument supplier.

The *p*H value of the solution shall be determined at (25 ± 1)°C in accordance with the test procedures as prescribed by the supplier of the measuring instrument.

Conductivity value measurements shall also be performed at (25 ± 1)°C in accordance with the test procedures as prescribed by the supplier of the conductivity measuring instrument.

The *p*H value and conductivity value shall preferably be read by using automatic temperature compensation. If such a facility is not available, the values shall be read when the temperature of the solution is at (25 ±1) °C.

NOTE — Automatic temperature compensation is usually an integral feature of the *p*H and conductivity measuring instruments.

J-2.6 Evaluation of the Test Results

From the two test determinations undertaken, the sample shall be considered to have met the performance requirement if both *p*H values are greater than or equal to the specified value and both conductivity values are less than or equal to the specified value.

J-3 DETERMINATION OF HALOGENS — ELEMENTAL TEST

WARNING — Owing to its potentially hazardous nature the fusion operation should be carried out in a fume cabinet, using safety screen.

J-3.1 Equipment

a) Bunsen burner;

b) Glass test tubes of approximately 50 mm × 10 mm;
c) Test tube holder;
d) Evaporating basin / mortar;
e) Wire gauge;
f) Funnel; and
g) Filter paper.

J-3.2 Materials

a) Sample;
b) Sodium metal;
c) Nitric acid (5 percent);
d) Aqueous silver nitrate (5 percent);
e) Freshly prepared zirconium-alizarin red reagent;
f) Glacial acetic acid; and
g) pH papers.

J-3.3 Procedure

J-3.3.1 *Sodium Fusion*

Place 200 to 250 mg of the sample into the bottom of a small soda glass test tube. Add 10 ml of de-ionized water to the evaporating basin and place this in the fume cupboard behind the safety screen. Whilst holding the test tube firmly with the test tube holder at an angle of 45° to 60° to the vertical, introduce a piece of freshly cut, clean sodium in size of a small pea (200 to 250 mg) into the mouth of the test tube without allowing it to come into contact with the sample directly. With the safety screen in place, heat the sodium gently until it melts and runs down on to the sample leading to vigorous reaction when the molten sodium reaches the sample in case of presence of halogen. Heat the test tube gently for about a minute, then more strongly until the lower 20 mm of the test tube glows red hot. Plunge the red hot tube into the water in the evaporating basin, immediately placing the gauze on the top, to prevent the loss of material when tube shatters on contact with water. Allow any unreacted sodium to react before grinding up the solution and glass. Filter and separate the filtrate into two equal portions.

J-3.4 Determination of Presence of Chlorine and Bromine

To the first portion of the filtrate, add sufficient nitric acid to make the solution acidic. Boil this total volume till reduced by half, to remove any HCN or H_2S, if present, which would interfere with the test. Add 1 ml of silver nitrate solution a white or yellowish precipitate indicates the presence of halogen (Cl, Br), in the original sample (if the liquor is decanted and the precipitate is white and readily soluble in dilute ammonia then chloride is present).

J-3.5 Determination of Presence of Fluorine

To the second portion of the filtrate, acidify with glacial acetic acid. Boil this solution until its total volume is reduced to half.

Add two to three drops of freshly prepared zirconium lake reagent (equal volume of)

a) Alizarin solution : Prepared by mixing 0.05 g alizarin Red –S in 50 ml distilled water.
b) Zirconium solution: 0.05g zirconium nitrate in 10 ml concentrated HCL diluted with 50 ml of distilled water.

Heat at 40°C for one hour. The presence of fluoride is indicated by the red / pink colouration being bleached to yellow.

J-4 DETERMINATION OF LOW LEVELS OF FLUORINE

J-4.1 Principle J-4.1.1 *General*

The sample is burnt in an oxygen flask, and the resulting solution is used to measure the fluorine content. The fluorine content may be measured using either of the following methods:

a) Method A — A fluoride ion selective electrode, or
b) Method B — Colourimetrically, by formation of the blue-red oligomer fluorine blue complex.

J-4.1.2 *Apparatus*

a) Oxygen flask;
b) Pipettes; and
c) Volumetric flasks.

NOTE — All apparatus used in the fluorine determination should be made of polycarbonate or polypropylene, as fluoride ions react with glassware.

For method A, ion selective electrode (fluoride) with suitable millivolt meter; for method B, visible spectrophotometer.

J-4.1.3 *Reagents*

a) Method A : electrode filling solution – buffer solution as recommended by electrode manufacturer.
b) Method B : alizarin fluorine blue reagent – dissolve 2.5 galizarin fluorine blue complex in 15 ml 2– propanol plus 35 ml water. Filter before use.
c) Standard fluoride solution prepared from sodium fluoride.
d) Dodecanol.
e) 0.5 M Sodium hydroxide solution.

J-4.2.2 *Procedure* **J-4.2.2.1** *General*

Place an accurately weighed sample of material (25 mg to 30 mg) in a 1 l oxygen flask using 2 to 3 drops of dodecanol on the sample to assist burning. Add 5 ml of 0.5 M sodium hydroxide solution as absorbant. Burn the sample and allow mist to settle. Transfer the contents of the flask with minimum washing to a 50 ml volumetric flask and proceed with method A or B.

J-4.2.2.2 *Method A — Ion selective electrode method fluoride*

Add 5 ml of recommended/buffer reagent to the sample solution and washings, and make up to the mark. Construct a calibration curve for the fluoride ion electrode according to the manufacturer's instructions. Measure the fluoride concentration of the sample solution and calculate the percentage of fluorine in the sample.

J-4.2.2.3 *Method B — Alizarin fluorine blue method*

Add 5 ml alizarin fluorine blue reagent to the sample solution and washings and make up to the mark. Allow to stand for the colour to develop. Measure the absorbance of the solution at 630 nm using a 1 cm cell with water as blank. Construct a calibration curve by suitably diluting the standard fluoride solution to give concentrations in the range 0 µg/ml to 2 µg/ml. Also measure the absorbance of a reagent blank using reagent and water only. Calculate the fluorine concentration in the sample.

J-4.2.3 Using this method, it is estimated that fluorine levels with values greater than 0.02 percent can be detected.

In order to determine total halogen content of the material under test, the methods described in **J-4.2.3.1** a) and b) shall be used.

J-4.2.3.1 *Acid gas generation*

a) Tests shall be performed in accordance with the method specified in IS 10810 (Part 59).
b) Tests shall be performed in accordance with the method specified in **J-2** .

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